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EFFICIENT SOLAR COLLECTOR MATERIAL AND WORKING

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ABSTRACT

This paper concentrates on different solar water heaters and control systems. Research is discussed on contributions and developments in solar energy collectors made up materials, heat transfer characteristics and manufacturing challenges. Comparative analysis in term of 4 % increase in performance of microchannel flat plate collector is discussed. Paper also focuses on recent technology developed using micro channels in flat plate collectors with actual temperature increase results. Suggestions have been raised for choosing the microchannel solar collector technology instead of evacuated tube collectors and flat plate tube type collectors.

KEYWORDS: Materials, Heat Transfer, Flat Plate Collector, Evacuated Tubes Solar Collector, Heat Pipe Tube Collector & Microchannel Flat Plate Solar Collectors

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Original Article

INTRODUCTION

Solar water heaters utilize energy for the purpose of heating water from the sun in the form of radiations during a sunny day for domestic and industrial purposes these days. The radiations are catched up with help of a heat absorbent coated and layered water pipes in which, water as fluid flows. (I, II, III). The material of the tube pipes is normally takes as copper, because of its large thermal properties. The water heated with this mean is used for cooking purposes in domestics and also used in textile industry, fabric dying etc.

In India, there is still 8 % population that uses a total of solar energy that comes from nature. If we look at the statics of the world health organization that around the globe, there are 12 million of deaths happening each year, due to the fumes inhaled by the persons that comes from the burning of the wood and coal. (IV, V, VI). These fumes give rise to various breathing diseases also, so with mean of time; there is developed kind of water heating machines that works on principal of natural thermosyphone, whereas in India, we receive 5×1015 kWh/year of solar energy (VII – XIII). We use this free energy for our use, by the mean of flat plate collectors, evacuated tube collectors, micro channel flat plate collectors (XVI, XV).

These solar energy collectors are possessed with a radiation collection mechanism that gives us enormous collector performance year ahead, along various weather conditions (XVI, XVII).There are many ways to talk about the performance of the collectors or to increase the working performance by increasing the surface area of contact of radiation, or by maintaining the angle of the collector (XVIII, XIX).

Solar Energy Collector Fabrication Material

A solar flat plate collector is mainly an assembly of transparent glass cover of 4 mm approximate thickness with four copper pipes of mainly each of 15 mm thick pipes, properly welded together with inlet hose pipe and outlet hose pipe. (XX, XXI). The choosing of material is the main aspect, which is usually taken of high heat carrying

capacity with large other thermal properties, so copper be the best as shown in the “figure 1”.

The “figure 2” shows the graph between the collector efficiency to the difference between collector and ambient temperature in °c. Main parts of graph system are the optical loss and the thermal losses. (XXII, XXIII).

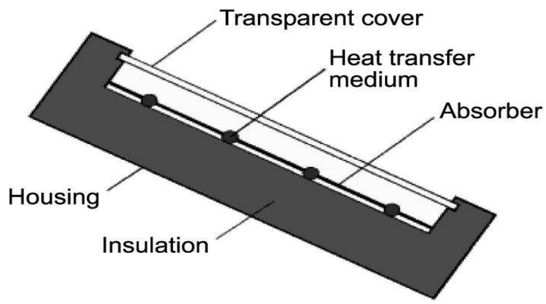

Figure 1: Flat Plate Collector (https://energy.gov/eere/solarpoweringamerica)

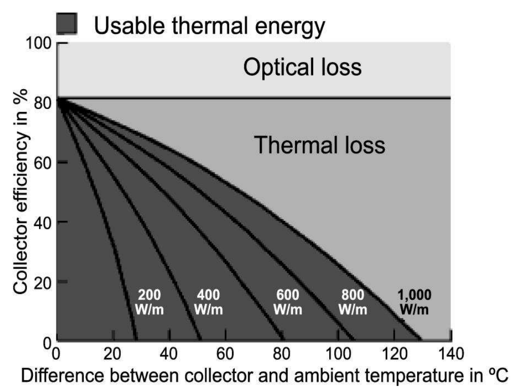

Figure 2: Efficiency graph of solar collector performance (www.solarserver.de/wissen/sonnenkollektoren-e.html#hoc)

Table 1: Types of Collector with its Conversion Factor and Thermal Loss Factor Around a Specific Temperature Difference (XXIV, XXV)

Type of collector	Conversion Factor	Thermal loss Factor (kW/m^2)	Temperature
Flat plate collector	0.66-0.83	2.9-5.3	20-80
Evacuated-plate collector	0.81-0.83	2.6-4.3	20-120
Reservoir collector	about 0.55	about 2.4	20-70
Evacuated-tube collector	0.62-0.84	0.7-2.0	50-120

The “Table 1” above shows there are four types of collectors, taken mainly showing their conversion factor ranging from 0.55 to 2.9 and having thermal loss factor considered in kW/m^2 from 0.7 to 2.9. (XXVI, XXVII). With rise in heat radiation, the temperature ranges are from 20° C to 120°C (XXVIII, XXIX).

INSULATION

Each collector that is meant for solar radiation absorption is always meant to heat losses either from the frame itself, or from the rough weather conditions, so insulation is very much important to prevent heat losses from back side of apparatus and from side walls of solar water heater. Insulation must be such like that, it be resistant to resist 150°C of temperature in collectors. Main type of insulator is of black paint with absorber properties and to hold 200°C of temperature. (XXIX)

The insulators used in today's absorbers are having properties which doesn't shrink, melt at high temperature radiation (XXX). These have specific properties also that, they didn't give off vapors which could condense on the collector cover and results in reduce its solar transmittance.

In today's times we use paint layered thin film temperature resistant insulation, which is always in contact with absorber. We use these because these are less expensive in cost (XXXI).

This procedure is always put in use, because of the water penetration risk in solar collector, so the thermal conductivity, durability properties are also considered (XXXII). In almost all the solar collectors, there is glass fibre used, which is easily available and cheap to purchase, whatever is the case of a small production or the big scale (XXXIII). Glass fibre insulation is cheap, but there are limitations in it, because it gets deteriorated whenever it comes in contact with water or moisture (XXXIV), so, it should be ventilated and supported enough, so that, there must be no blockage in it. In today's times, there is also a material called mineral wool, popular enough for attaining the higher temperatures having a little expensive which increases the collector box.

FRAME

In the body of a collector, there is a rigid structure, which has to hold whole of the structure of pipes and other things attached with it, such as glass wool. The cover glass weight, which is of 4mm in width's weight, has to be carried over by the frame also.

The frame provides toughness to structure of the collector, and is designed with light material aluminium extruded profiles. The frame is anodized painted for the corrosion protection from the sides. Another material as galvanized steel sheet is used having thickness of order 0.5-1.0 mm. (XXXV). The frame and the glass cover are mainly important for the effective flow, such like in case of microchannel solar water collector for collector's better reliability.

Frame is also used for the protection from losses, caused due to wind, so absorber is provided and glazing is done in. These are made up of various materials like aluminium sheet extrusion, welded and formed.

The frame is such a way made to withstand weather conditions, proof from fire, durable, strong and permanently sealed against moisture effects. In the frame, the number of joints and seams must be minimized enough to make it sealed from foreign particles like salt air, pollution from industry, smog in atmosphere (XXXVI).

COLLECTOR SEALANTS

All the solar collectors depend strongly upon the sealing assembly around the cover body and the water fluid inlet and outlet pipe connections.

Sealants must have the property to withstand high temperatures and rough weather conditions. They must possess flexibility to water tightness and thermal movement of the collector components, whenever the frame is dismantled for maintenance through their lifetime. Sealants must withstand attack by birds also. Ethylene propylene or Diene monomer are used as sealants in all solar collectors.

These have high withstanding to high temperatures, salty rains, acid rains etc. The costing is very high of this sealant and is durable.

THERMAL COLLECTOR'S BODY COATING MATERIALS

This is the method, where we do paint the selective plastic material on sides of steel boxes, inner side and outside, if necessary such like in the hot water storage tanks. The plastic coatings must be prevented from contact with any kind of food contact. These coatings are done for the corrosion protection. This becomes useful to seal edges of joints done by welding or by riveting. The process of coating involves raising the temperature of box or tank extruded of welded frame to 260°C, and plastic material is applied on all side corners as well body of thickness ranging from 0.320 mm.

Table 2: Material Thermal Conductivity (XXXVII)

Material	Thermal Conductivity (W/m8C) at 258^{o} C	Specific Heat Capacity – Cp(kJ/kg K)
Silver	429	0.23
Copper	401	0.39
Gold	310	0.13
Aluminium	250	0.91
Brass	109	n/a
Iron	80	0.46
Steel	46	0.5

SOLAR THERMAL EVACUATED TUBULAR COLLECTORS

The evacuated tube collectors in "figure 3" consists of a large 150 mm diameter glass tubes made up of borosilicate material with small tubes of 65 mm appox, based on iron soda lime glass (XXXVII). The phenomenon behind the working of tubes is that, the heat transfer fluid flows directly through the metallic absorber with, also the absorber tube is realized as a heat pipe system.

Table 3: Evacuated Tubes Manufacturing Specification (XXXVIII)

S. No.	Tube Part	Specification
1	Absorber	Copper tubes ultrasonically welded on copper sheet metal
2	Coating	Spectrally selective absorber coating, black chrome directly on copper sheet metal
3	Tube	Borosilicate glass
4	Tube distance	112mm from centre to centre in a tube case

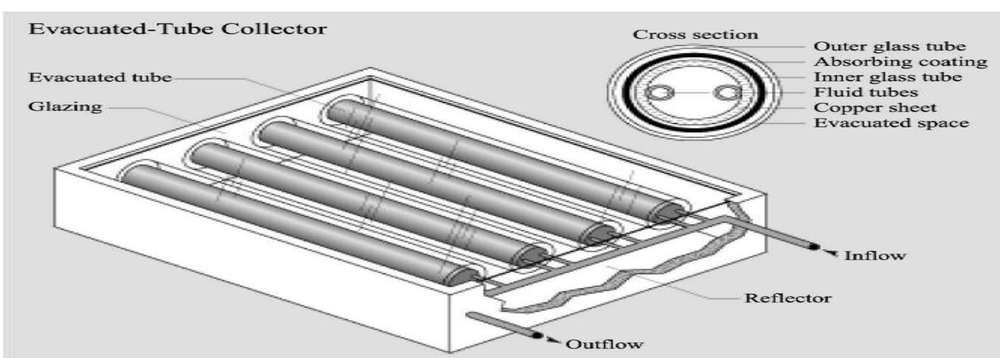

Figure 3: Evacuated-Tube Collector (XXXII)

Performance of the tube type collector is quite high, because the radiation can be absorbed from all sides of the tubes as in comparison with the flat plate collector. That's why, where a large amount of sunny weather conditions are possible, there an extreme temperature of 250°C can be achieved. But, its handling costs are very high because of fragility in the nature of all glass made.

Silent Features of Tubes

- The part namimgcombine glass vacuum tube and copper heat pipe as one unit making it simple in design.
- The use of super-conducting working liquid in copper heat pipe makes it highly efficient in gaining high thermal properties.
- The evacuated tubes have very high degree of vacuum.
- In evacuated tubes, without water flow in glass vacuum tube, so it can bear an -2308°C of cold temperature conditions.
- The evacuated tubes find application in high pressure solar water heater and solar projects.

Energy Gain Graph Year Wise (Flat Plate Vs Tubular Collectors)

In the Figure – 4, there is a wide range of yearly heat gained vs. number of years from 1970 to 2010 has been shown, as a part that the efficiency of the tube type evacuated collectors and flat plate collectors with small difference of temperature performance gained in years.

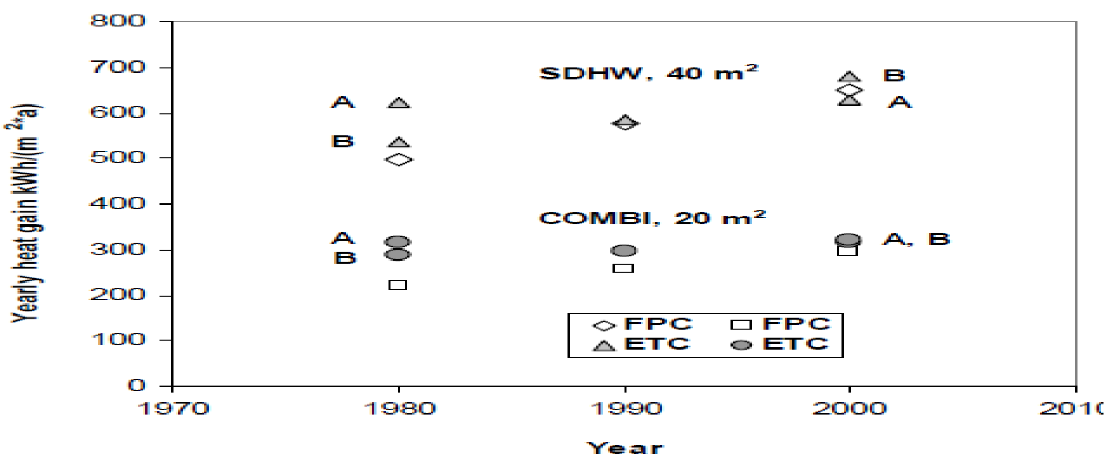

Figure 4: Comparison of Flat Plate and Tubular Collectors (J. (2004) XXXI)

MICROCHANNEL TYPE FLAT PLATE SOLAR COLLECTOR

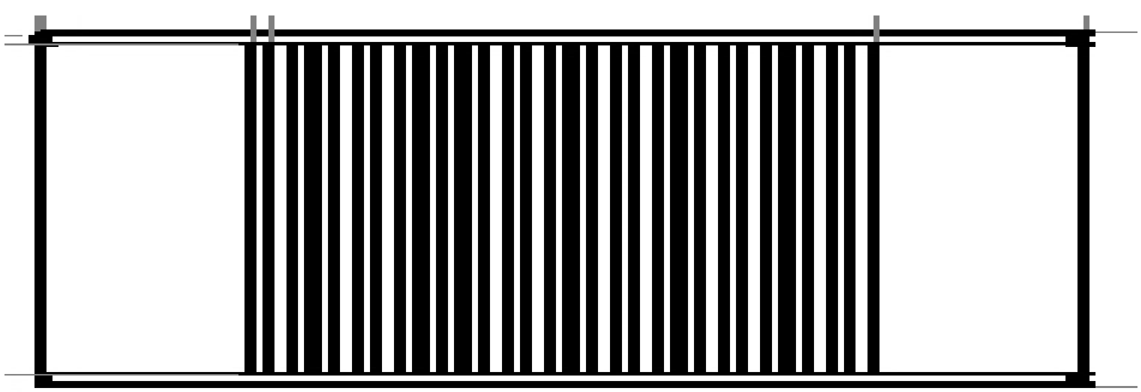

Figure 5: Simulated Microchannel Flat Plate Solar Collector
(For Simulation with Water in Solid Works Software)

Figure 6A: Original Machined Microchannelsolar Flat Plat Collector with Various Channels Milled on Vertical Milling Machine

Figure 6 B: Solar Testing Panel from Ecoscence for Microchannel Testing

These types of collectors are introduced these days on the idea of increasing the surface area, so that, the contact surface of plate may absorb maximum solar radiation. For selection of material to manufacture these type of special collectors, normally of high thermal efficient materials be selected, like copper. A microchannel is a 1mm wide and 600 mm length slot. The material taken may be copper or aluminium, depending upon the requirement also. Efficiency of such like solar collector is found to be 40 % as 10 % higher than the tube type solar collector or evacuated tube type collectors.

Table 4: Material Density (M. (1986) XXXI)

Material	Thermal Conductivity (W/m K)
Copper	385.0
Gold	314
Brass	109.0
Aluminum	205.0

Table 5: Material Thermal Conductivity (XXXII)

Metal	Density g/cm^3	Density lb/in^3
Iron	7.8700	0.284000
copper	8.9600	0.324000
Silver	10.4900	0.37900
Lead	11.3600	0.41000

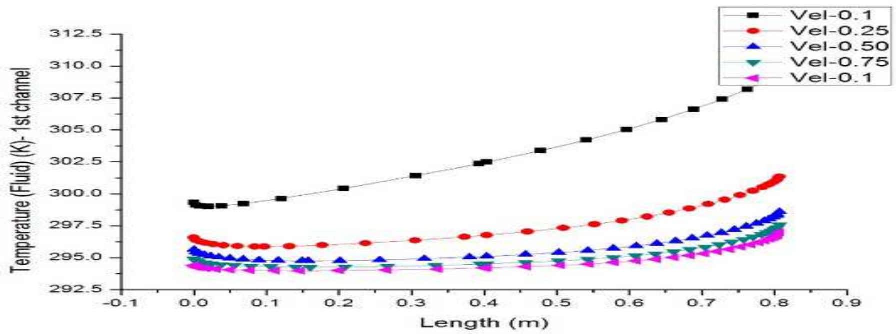

Figure 7: Temperature Performance Comparison Graph at 1st Channel with Various Velocities on Microchannel Flat Plate Solar Collector

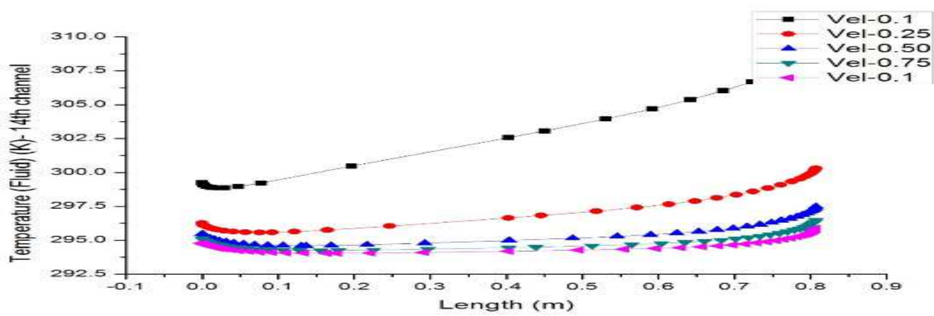

Figure 8: Temperature Comparison Graph at 14th Channel with Various Velocities on Microchannel Flat Plate Solar Collector

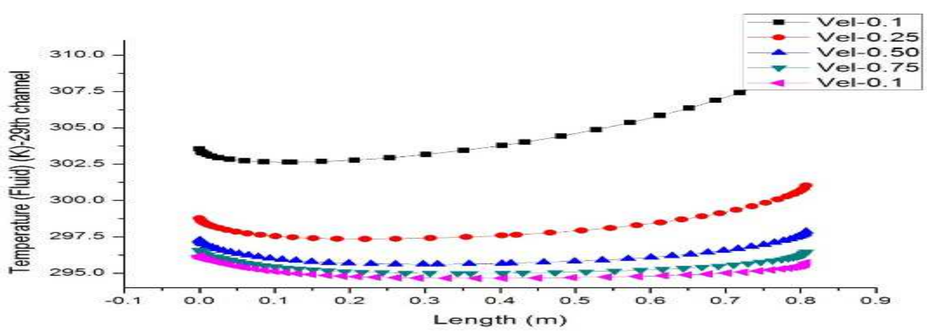

Figure 9: Temperature Comparison Graph at 29th Channel with Various Velocities on Microchannel Flat Plate Solar Collector

The selection of material depends upon the density of material such like shown in the above table of metals, with their thermal conductivity, which is found to be of copper, as the highest.

The use of microchannel flat plate collector results in

- Reduced cost of materials and manufacture.
- Resistance to corrosion build-up, where maintenance costs will be lower.
- Reduced weight and easy installation.
- Simulated results show a 4 % increase in efficiency at 0.1 velocities.

CONCLUSIONS

- The material copper selected to manufacture microchannel collectors.
- Glass as transparent cover which is relatively inexpensive.
- Vacuum insulation a no cost material.
- Selective coating material which is relatively cheap, as compared to high output of energy of solar collector.
- Super conducting working fluid water (very low cost).
- Micro channel flat plate solar collector with principal based upon to increase the surface area for heat radiations collection has gained more heat and working efficiency as shown in graphs
- High temperature rate of 4 % is attained during experimentation on solar testing machine using micro channel flat plate collector in comparison with conventional tube type collector and evacuated tube collector experimentally.

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